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a 19-page report dated 20 Mar 61 written by Depl Eng Milan Dobrovic, of Ivornica elektroda i ferolegura, Sibenik, (Croatia) Yugoslavia. The report deals with Dr Dobrovic's study of ferrotitanium production in the USSR and plans for a ferrotitanium plant in Yugoslavia.

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Ferrotitanium Production in the USSR

Plans for Ferrotitanium Production in Sibenik, Yugoslavia

In the development of the steel industry the production of alloy steels brought forth a demand for alloying agents. These are the substances in general termed the ferroalloys.

Ferrotitanium is a ferroalloy of titanium with iron, containing very small quantity of others elements: carbon, aluminium, silicon, copper, phosphorus and sulphur. These impurities enter in to the ferrotitanium during the process of production.

Yugoslave standard specifications for the ferrotitanium are given in the table 1.

Product	Type	Chemical composition							
		Ti %	C %	Al %	Si %	Cu %	As %	Si/Ti	Al/Ti
FeTi (produced by electrothermic process)	I.	15,0	5,0	-	-	-	-	-	-
	II.	20,0	10,0	-	-	-	-	-	-
FeTi (produced by aluminothermic process)	I.	20,0	max	6,0	1,0	2,0	max	0,05	0,30
	II.	40,0	0,10	13,0	3,0	3,0	0,10	0,075	0,33

TABLE 1 Jugoslave standard specifications for ferrotitanium (Steel work Jesenice)

Ferrotitanium produced by electrothermic process, using carbon as reducing agent, contains great amount of carbon, hence its use in steel industry is limited.

Nowadays in U.S.S.R. the ferrotitanium is produced by aluminothermic method. Russian standard specifications for ferrotitanium can be seen in the table 2.

Type of FeTi	Composition							
	Ti % min	C % max	Al %	Si %	Ca %	P, S %	Si/Ti	Al/Ti
Ti-0	25,0	0,15	6,2	4,5	3,0	0,10	0,18	0,25
Ti-1	23,0	0,15	6,2	4,6	3,0	0,10	0,20	0,27
Ti-2	23,0	0,20	9,2	6,4	4,0	0,16	0,28	0,40

TABLE 2. Russian standard specifications for ferro titanium (production by aluminothermic method)
ALUMINOTHERMIC METHOD

Ferrotitanium finds use in steel industry as an alloying agent as well as a desoxidiser. It also finde use in the manufacture of welding electrodes.

In U.S.S.R. the steel production is in a steady development. In the next 15 years it is forseen that the annual production would increase to 100 - 120 million tons. A large portion of this production is expected to be in the form of alloy steels, which indicate an increased domand for the ferroalloys produced by the aluminothermic method.

Aluminothermic process is based on the reduction of metallic oxides with aluminium, and can be presented by the following reaction :

$$TiO_2 + 4/3\ Al = Ti + 2/3\ Al_2O_3$$

However, at the same time the following reactions take place:

$$TiO_2 + 1/3\ Al = 1/2\ Ti_2O_3 + 1/6\ Al_2O_3$$

$$2\ TiO_2 + 4/3\ Al = 2\ TiO + 2/3\ Al_2O_3$$

$$Ti_2O_3 + 2/3\ Al = 2\ TiO + 1/3\ Al_2O_3$$

Titanium oxides go in to the slag.

The advantages of aluminothermic method are as follows :

1) The posibility to obtain ferrotitanium with low carbon
2) The great speed of process
3) Simple equipment

Disadvantages of this method are :

1) The great content of aluminium in the ferrotitanium
2) High price of aluminium

In U.S.S.R. the industrial production of ferrotitanium began in 1937 in electrical furnaces. In the same year the Institute of Metals initiated a process for aluminothermic production of ferrotitanium without electrical furnace.

In 1953 this method for production of 25 -30 % FeTi was fully developed on industrial scale. Today, it is by this method that all the ferrotitanium in U.S.S.R. is produced.

The ferrotitanium production in U.S.S.R. in 1960 was about 30.000 tons. Half of that was produced in the factory of ferroalloys in Lipetzk.

Yugoslavia, as a socialist country, with steady expansion of steel industry, has no industrial production of ferrotitanium,at all.

That led the Government of Yugoslavia to nominate me for a United Nations fellowship to study the production of ferrotitanium in U.S.S.R.

Situation in Yugoslavia in view of ferrotitanium production

According to some provisions in 1963, Yugoslavia will need about 143 tons ferrotitanium.

Yugoslavia does not produce ferrotitanium and all demand of this alloy is imported.

On the other hand, the production of ferroalloys in Yugoslavia is very much developed. There are electric furnaces in Jajce, Dugi Rat, Ruse and Sibenik.

After the second world war new factories of ferro-alloys are built in Jegunovce and Sibenik.

In the past in Electrodes and ferroalloys plant in Sibenik ferromolybdenum and ferrotungsten have been produced. There is some equipment in this plant which can be used for ferro-titanium production. Especially the rocking furnace in the new part of the plant, in which the low carbon ferromanganese is produced, could be used for ferrotitanium production.

The above mentioned equipments can be seen in the Fig.1, 2, 3.

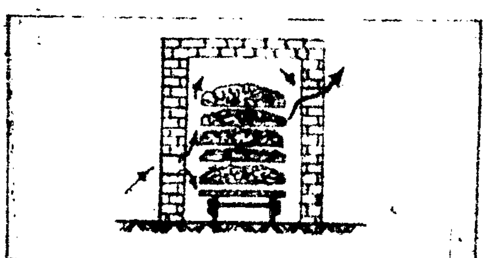

Fig 1 Calcining oven presently used for Scheelite but could be used for Ti-concentrate

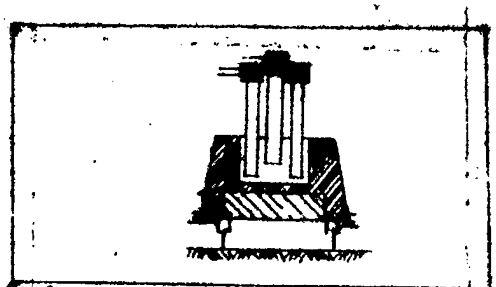

FIG 2 150 KVA threephase furnace presently used for ferro-Tungsten but could be used for ferro-Titanium.

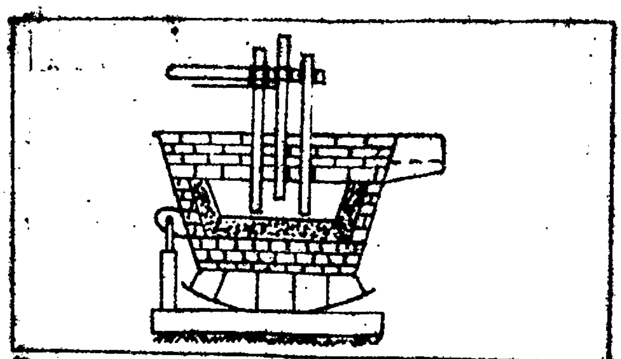

FIG. 3 1500 KVA threephase furnace presently used for production of Low carbon Ferro-manganese but could be used for FeTi.

Aditional main equipment for ferrotitanium production which must be instaled is the following :

1) Rotary kiln, refractory-lined, for calcining
2) Equipment for production of Al-metal powder, in case if not intended to purchase ready powder
3) Equipment for grinding and screening
4) Crucibles for fusion
5) Screw conveyor
6) Storage silos
7) Equipment for mixing
8) Weighing equipment

The most important question for the production of ferretitanium is row materials.

For the production of ferretitanium by aluminothermic method the titanium concentrate must corespond to the specification given in the table 3.

	I.	II.	III.
TiO_2 min	42,0	40,0	38,0
Fe_2O_3	53,6	53,6	53,6
SiO_2	2,5	2,5	4,0
moisture	7,0	7,0	10,0
P	0,05	0,05	0,05

TABLE 3. Russian specifications for ilmenite concentrate.

In Yugoslavia there is no production of titanium concentrate, therefore the experiments have been made to use the red mud, which aglomerated contains about 7.4% TiO_2, as row material for ferretitanium production. In the experiments already caried out in Sibenik, aglomerated red mud was reduced in electric furnace with carbon. Titanium goes in to the slag. Reducing titanium-slag again in electric furnace with carbon, the metal of follwing composition was obtained :

Ti	=	11,39 %	C	=	2,55 %
V	=	0,18 %	Si	=	12,01 %
Cr	=	0,22 %	Mn	=	7,71 %
P	=	0,093%	Fe	=	59,87 %
S	=	0,025 %	Al	=	5,82 %

Also, in Yugoslavia, experiments have been made to separate the titanium and other useful components from the red mud by means of acids.

The production of ferrotitanium in U.S.S.R.

The factory of ferroalloys in Lipetsk (U.S.S.R.) is built in 1935 and put in to the operation in 1939. At first the factory produced calcium carbide. During the second world-war there was great demand for ferrosilicon and ferrotitanium. Till 1943 the preparations for these productions were made and in 1948 the production of ferrotitanium was started.

From 1948 till 1960 the production of ferrotitanium has increased by 25 times in this plant.

The technological process of ferrotitanium production in the factory of ferroalloys in Lipetsk is represented in the Fig.4.

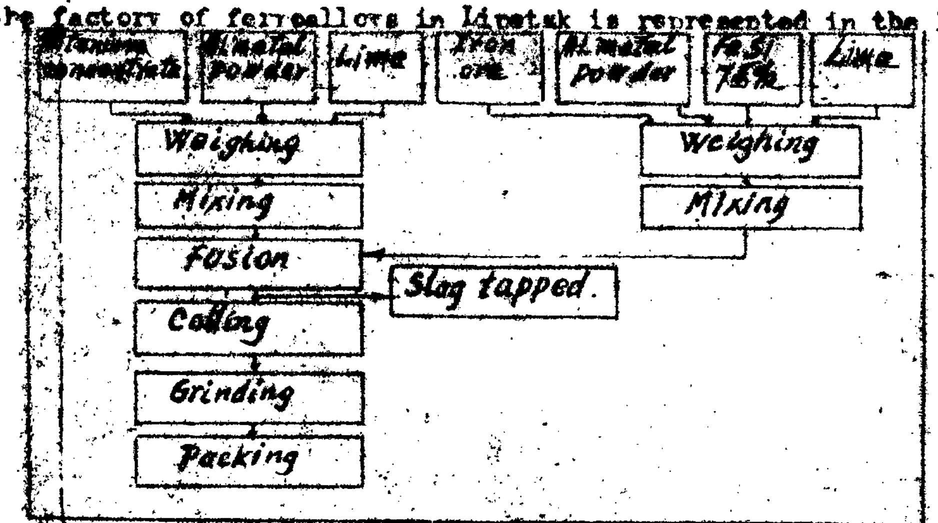

Fig 4. Flowsheet of technological process of ferrotitanium production plant in the [illegible] in Lipetsk [illegible]

The raw materials for the production of ferrotitanium are :

ferroalloys in Lipetzk (USSR)

1) Titanium concentrate
2) Al-metal powder
3) Lime
4) Iron ore
5) Ferrosilicon 75 %

The analisis of diff. grades of titanium concentrates are given in the table 4.

Grades % / Concentrates	TiO_2	FeO	Fe_2O_3	SiO_2	MnO	CaO	Al_2O_3	V_2O_5	S
Titanomagnetite	38,6	22,3	28,4	3,6	1,1	0,7	1,6	0,6	0,6
" "	42,8	18,6	33,1	2,8	1,2	0,5	1,4	0,5	0,5
Ilmenite	44,5	45,9	-	1,9	1,6	0,5	1,4	0,4	0,03
"	50,4	44,2	-	1,6	1,7	0,4	1,3	0,5	0,01

TABLE 4 Analysis of titanium concentrates

Titano-magnetite concentrates contain too much sulphur and they have to be calcined.

The calcination in the rotary kiln, has following purposes:

1) To diminish the content of sulphur

2) To oxydise the iron oxide from Fe^{O} to Fe_2O_3

The diminution of sulphur in titanium concentrate dipends upon the temperature of calcination and is shown in the Fig. 5.

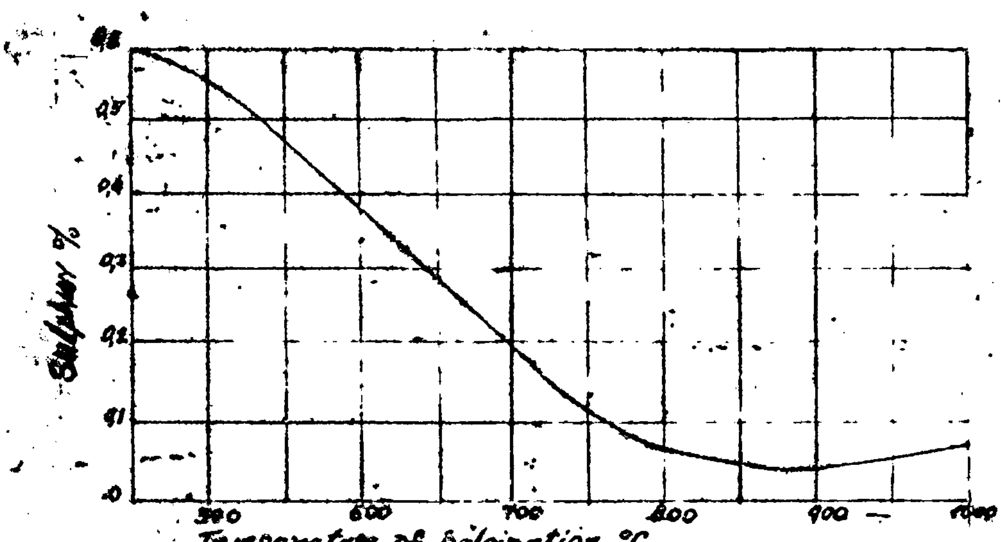

Fig.5. Diagram showing the relation between the temperature of calcination and diminution of sulphur in titanium concentrate.

Oxydation of Fe^0 goes through the following phases :

Fe^0 = Fe_3O_4

Fe_3O_4 = - Fe_2O_3

- Fe_2O_3 = -- Fe_2O_3

Condisering the thermal energy requirements, the required specific calcric effect for the aluminothermic process is:

= 55o Kcal/kg

In the table 5 is given the data of the oxides for the specific caloric effect of titanium and ferrous oxides.

	Oxydes			
	TiO_2	Fe_2O_3	Fe_3O_4	FeO
Specific caloric effect kcal/kg	372	918	848	730

TABLE 5. Specific caloric effect of titanium and iron oxydes

As evident from table 5, the amount of heat energy liberated during the reduction of TiO_2 is less than the minimum required calories.

However, during the reduction of higher iron oxides a larger amount of heat energy is liberated. This provids for the necessary thermal energy requirement of the process.

It is by calcination process that the Fe_2O_3 is obtained. This presents the necessity for calcination of the concestrates.

After the calcination, the titanium concentrate is screened through 3 mm size screen.

The second grade Al-powder is used as reducing agent in the process. The specification of the secon grade Al-metal used for making Al-powder is shrown in table 6.

Type of aluminium	Chemical analysis							
	Al	Fe	Si	Cu	Mn	Mg	Zn	Pb+Sn+Ni
	min	max						
AM-2*	92	0,8	1,0	3,0	0,32	0,5	0,5	0,3
AM-2	90	1,2	2,0	3,5	0,35	0,6	0,5	0,4
AM-3	87	1,4	3,0	3,8	0,40	0,8	0,8	0,5
ACV	84	1,5	4,0	4,0	0,50	0,5	4,0	0,5

TABLE 6. The quality of second grade aluminium used for preparation of aluminium powder.

The process of making Al-powder consists of dispersion by compressed air of the fluidised metal. Al-metal powder must corespond to the specifications given in the table 7.

Grain size	0,0-0,1 mm	0,1-1,5 mm	1,5-3,0 mm	3-[illegible] mm
Percentage	Max 10%	min 80%	max 9%	Max 1%

TABLE 7. Specifications for Al-metal powder

Before using Al-metal powder is screened through 5 mm size screen.

For obtaining low temp. meting slag, lime is used. The lime must contain min. 90% CaO in grains size 1,5 - 3,0 mm. So lime must be grinded and screened.

Iron ore is added in the end of process in mixture with lime, Al-metal powder and 75% FeSi in order to increase the thermal effect and to obtain better separation of metal from the slag. Iron ore must contain min. 95 % Fe_2O_3 and should be dry and screened through 3 mm size screen.

Drying of iron ore is executed in the same rotary kiln which is used for calcination of titanium concentrates.

75% ferrosilicon is used in small quantity to replace one small part of Al-metal powder in thermic mixture for reduction of iron ore. Ferrosilicon is grinded and screened through the screen 2 - 3 mm.

The fusion is carried out in crucibles made from cast iron. The crucible is made of four section, and has capacity of 1o tone charging m mixture. When crucible is ready for fusion, and charging mixture prepared, the worker takes a small quantity of the charging mixture, and light it with electrical spark from a 12 V supply, and puts it in crucible in which is already 2oo-3oo kg of charging mixture. After that the charging mixture is added little by little by means of screw conveyor. The charging mixture is composed of titanium concentrate Al-metal powder and lime. After the charging mixture additional thermic mixture is added by the same screw conveyor. Thermic mixture is composed of iron ore, lime, Al-metal powder and 75 % FeSi.

A charging mixture contains for instance :

Titano magnetite concentrate		5.ooo kg
Ilmenite concentrate		1.ooo kg
Al-metal powder Ac 3		2.5oo kg
Lime		5oo kg
	Total :	[illegible],1OO kg

Thermic mixture is composed of :

Iron ore		5oo kg
Ferrosilicon 75 %		1oo kg
Al-metal Ac 3		7o kg
Lime		7o kg
	Total :	74o kg

From 9.84o kg of row materials about 4.3oo kg of FeTi (28 % Ti) are obtained and 5.3oo slag is formed.

The composition of slag is given in table 8.

Slag	Oxydes					
	TiO_2	Al_2O_3	SiO_2	FeO	CO	CuO
1.	12,42	72,16	0,94	1,26	[illegible]	[illegible]
2.	12,61	72,48	0,98	1,36	8,92	0,11
3.	13,08	73,41	1,04	1,33	9,08	0,08

TABLE 8. The composition of ferrotitanium slag.

The distribution of time is as follows :

Weighing row materials	1 hrs
Fusion	½ hrs
Cooling	18 hrs
Total.	19½ hrs

The consumption of row materials per tone ferrotitanium in 1960 was as follows:

Titanium concentrate	1097,1 kg/ton
Al-metal powder	475,1 "
Lime	102,9 "
Iron ore	97,4 "
Ferrosilicon 75 %	19,6 "

The costs of production is given as follows :

Titanium concentrate	509 P
Al-metal powder	1295 P
Lime	7 P
Iron ore	7 P
Ferrosilicon 75 %	30 P
Others costs	396 P
Costs of production	2244 P x

We see that 57 % of cost is due to the Al-metal powder. In order to reduce the cost of ferrotitaniu, the expereiments have been made to reduce consumption of Al-metal powder. They made fusion in a rocking electric furnace, and instead of thermic mixture they put in additional heat energy requirements by way of electric power; the electrodes dipping in the slag and keeping the current on for 1o - 2o minutes. In that way the consumption of Al-metal powder was diminuished by 5 - 6 %.

P r o p o s i t i o n s

I suggest to Government of Yugoslavia to introduce the production of ferrotitanium in the factory of electrodes and ferroalloys in Sibenik.

This factory is the most suitable since it is situated on the sea side and provids extra facility for the import of row materials and export of the product by way of sea transport, which is the cheapest mode of transport, completely avoiding the need for any land transportation.

The aluminothermic method can be used not only for ferrotitanium, but also for many other products as low carbon FeMn, ferromolibdenum, ferrotungsten, ferrovandadin, ferrotantal, ferroniobium, ferroboron, etc, which Yugoslavia already needs, or will be in need very soon. Therefore it is necessary that one factory in Yugoslavia has experiance in aluminothermic way of production.

Yugoslave perspective needs in special ferroalloys are given in table 9.

Ferroalloys	Tons
Low carbon FeMn with 0,1 % C	25
Ferromolibdenum 60%	200
Ferrotungsten 80%	250
Ferrovanadin	240
Ferrotitanium	143
Ferrotantal	1
Ferroniobium	1
Ferro boron	0,5

TABLE 9. Perspective needs of special ferroalloys in 1963.

On the other hand, the production of above mentioned ferroalloys can be profitable.

It is interesting to mention that it is only the ferrotitanium production which has yielded profits in the works in Lipetsk.

The costs of production of all other ferroalloys are higher than their market value.

In the table 10 are given the costs of production and costs of sale for ferroalloys produced in the factory of ferroalloys in Lipetzk (U.S.S.R.)

Ferroalloys	costs per ton of production * P	selling price P	Loss P	Profit P
CaC_2	114	71	43	–
FeSi 75%	139	92	47	–
FeSi 45%	82	64	18	–
FeTi 25%	224	362	–	138

TABLE 10. The costs of production and costs of sale for products in the factory of ferroalloys Lipetzk (USSR)
* new rubles

In order to introduce the production of ferrotitanium in Sibenik, it is necessary to buy titano-magnetite concentrate or ilmenite concentrate. It is better to by ilmenite concentrate because it can be used without calcination. Also, I propose to buy Al-metal powder instead of making it.

The others row materials: lime, iron ore and ferrosilicon are in the country. Ferrosilicon 75 % is produced in the factory of ferroalloys in Sibenik, and lime of the country is of very good quality.

The necessary equipment is simple and can be made with little investment.

From the equipment it is necessary only :

1) Equipment for grinding and screening
2) Crucibles for fusion (in case if rocking furnace will not be used)
3) Screw conveyer
4) Storage siloe (There are some siloe from FeW Production)
5) Equipment for mixing
6) Weighing equipment

Instead of iron ore the red mud can be used in charging mixture or in thermic mixture. Aglomerated red mud from aluminimu industry in Sibenik contains about 7,4 % TiO_2 and 42,82 % Fe.

The exploitation of red mud from event. hungarian bouxites is also suggested to the factory of ferroalloys in Lipetzk during my stay there.

Application of red mud in the production of ferro-titanium instead of iron ore must give better efficiency of Ti and diminuish the consumption of iron ore